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Bright-Band Modeling of Air/Space-Borne Microwave Radars

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***Abstract*- In simulating the radar echo in the melting layer of stratiform rain, a melting snowflake is modeled as a spherica non-uniform mixture, prescribed as a stratified-sphere in that the fractional water content is given as a function of the radius of sphere. Combined with the melting layer model that depict the melting fractions and fall velocities of hydrometeors, the radar profiles are produced and then compared with the measurements of TRMM PR and the dual-wavelength airborne radar.**

I. Introduction

The bright band of enhanced radar reflectivity is often observed in the layer where the melting of snow takes place. Understanding the effect of melting hydrometeors on the electric wave propagation is important for algorithms that are used to retrieve rain rates from spaceborne sensors, such as the Tropical Rainfall Measuring Mission (TRMM) Precipitation Radar (PR) and the TRMM Microwave Imager (TMI). Aside from the bright band model needed for simulations of the radar profiles in the melting region, correctly modeling snowflake melting process is also important in the simulation of the radar bright-band profile. The bright band, or melting layer model that describes the complex dynamical and thermodynamical processes within the melting layer, provides the data of the water fractions and fall velocities of the melting snow as a function of the particle size and the distance from the 0^0C isotherm. The melting snow model, on the other hand, describes how the melting process takes place. Two melting models often appear in the literatures: One is the uniformly-mixed model where the water fraction is constant throughout the particle, and another is concentric-sphere model where the water is confined to the outer shell and snow to the inner core. However, many observations [1] suggest that melting of the snowflake starts at its surface and gradually develops towards the center. It therefore becomes more realistic to model a melting snowflake as non-uniform mixture. To compute the scattering properties of such non-uniform melting particles, the stratified-sphere (or multi-layer sphere) scattering model is used, in which a uniform mixture is assumed within each layer with a water fraction that varies with radius. The advantage of using the stratified-sphere model is not only that the melting snowflake can be more realistically prescribed, but its analytical solution exists [2][3]. Having described the stratified-sphere model in Section II, the simulations of the radar bright-band profiles for the cases of TRMM PR and dual-wavelength airborne radar are made in Section III. The results reveal that the simulated profiles agree reasonably well with the measurements.

II. Melting snowflakes

As mentioned previously, the stratified sphere provides a great flexibility to model non-uniform snow-water mixtures in which the fractional water content is given as a function of the radius. The stratified-sphere melting model, used in this study, is composed of 100 equal-thickness layers, and an exponential equation is employed to describe the distribution of the fractional water content of melting snow. In Fig.1 examples are shown of melting particles with the water fractions of 0.2 (left) and 0.4 (right). The gray levels represent the values of water fractions within the particle. The effective dielectric constant of the uniform mixture, applied in each layer of the stratified sphere, is derived from the internal electric fields of the mixture by use of a conjugate gradient-fast Fourier transform (CGFFT) numerical method [4]. The snow density used is uniform within the particle, whereas some measurements indicate that the snow density decreases with increase of radius. However, studies have demonstrated that the difference of the effective dielectric constants between the uniform snow density and non-uniform snow density with the same average density as the uniform case are negligible small [5].

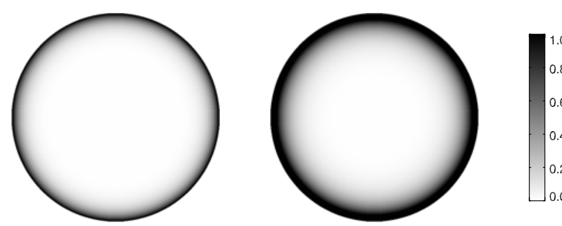

Fig.1. Examples of stratified-sphere model for the melting snowflakes for the overall water fractions of 0.2 (left) and 0.4 (right). The gray levels represents the fractional water contents.

IV. Summary

To use a more realistic melting model, the melting snowflake is modeled as a stratified sphere where the fractional water content is given as a function of the radius. Using this model the simulations of the radar reflectivity profiles associated with the melting layer are made for the cases of the TRMM PR and the dual-wavelength airborne radar. The raindrop size distributions, as input parameters of the melting model, are determined by matching the simulated and measured reflectivity in rain. For TRMM PR the Marshall-Palmer drop size distribution is used, while the 2-parameter exponential form of size distribution is applied for the airborne radar. In the simulations the same melting model is applied for TRMM PR and dual-wavelength airborne radar in the sense that the distributions of the fractional water contents within the melting snowflakes are treated the exactly same. The simulated bright-band profiles are in good agreement with the measured ones.